NEMA NU4 performance evaluation of the SynchroPET human arterial PET (ArterialPET) scanner for standalone blood input function

Nicolas A. Karakatsanis[1], Edward K. Fung[1], Mercy Akerele[1], Louiz Pollanz[2], Robert Gross[2], Yegor Sinelinkov[2], Tom Mariner[2], Marc Alessi[2], John Babich[1], Sadek A. Nehmeh[1]

[1]Department of Radiology, Weill Cornell Medical College, Cornell University, New York, NY [2]SynchroPET, Inc., Stony Brook, NY,

INTRODUCTION

- Dynamic PET measures the spatiotemporal distribution of radiotracers activity concentration in tissue and blood (arterial input function, AIF)
  - enables quantification of radiotracer's kinetics beyond SUV [1]
- Arterial blood sampling (ABS): gold-standard method to measure AIF
  - invasive, associated with high risk and complexity [2]
- Image-derived input function (IDIF): non-invasive clinically adoptable method to estimate AIF from large blood pool regions drawn on dynamic PET images [3]
  - Requires scanning patient in the scanner for long periods of time
  - Limited access to large blood pools with short axial FOV scanners

AIM

Assess the NEMA performance of the SynchroPET, Inc. (Stony Brook, NY) human arterial PET scanner prototype (ArterialPET^{TM}) designed for standalone 4-dimensional (4D) imaging of the human wrist to enable non-invasive quantitative blood input function measurements.

MATERIALS & METHODS

ArterialPET^{TM} encompasses

- 24 detector modules (1 block ring) with inner diameter of 9 cm.
- Module: 4 (transaxial) x 8 (axial) LSO crystals (2.3125 x 2.3125 x 6 mm^3)
- List-mode acquisition of prompts and delayed randoms coincidences
- Sinogram matrix: 59 (radial) x 48 (angular) x 64 (planes) bins.
- 3D PET normalization factors calculated with component-based method
  - rod source continuously rotating around the circumference of the transaxial FOV. (Fig. 1)
- Pet Image Reconstruction:
  - analytic 3D (FBP)
  - statistical 3D OS-EM (4 subsets
  - 3D images: 59 x 59 x 15 voxels
    - 1.254 x 1.254 x 1.15625 mm
  - image FOV:
    - 74mm diameter,
    - 17.3 mm axial FOV length
  - supports open-source Software for Tomographic Image Reconstruction (STIR) [4]
- NEMA NU 4-2008 standards:
  - Image Quality, Spatial Resolution, System Sensitivity

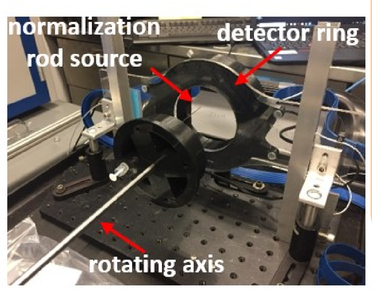


Figure 1. Geometry of ArterialPET and experimental set-up for acquisition of 3D normalization data

RESULTS

Spatial Resolution

- Average of radial and tangential resolution
  - 1.49 mm FWHM (2.72 mm FWTM) @ 5mm radial distance from center:
  - 2.78 mm FWHM (5.07 mm FWTM) @ 25 mm radial distance from center
- Axial resolution
  - 2.84mm FWHM (5.18mm FWTM) @ 5mm radial distance from center
  - 4.69mm FWHM (8.57mm FWTM). @ 25 mm radial distance from center

Spatial Resolution	FWHM & FWTM (mm) averaged between 2 slices: @ axial center & @ 1/4 axial FOV distance from center									
	0 mm		5mm		10mm		15mm		25mm	
	FWHM	FWTM	FWHM	FWTM	FWHM	FWTM	FWHM	FWTM	FWHM	FWTM
Radial	1.493	2.727	1.539	2.810	1.188	2.170	3.021	5.518	3.386	6.184
Tangential	1.213	2.216	1.441	2.632	2.609	4.765	2.409	4.400	2.168	3.959
Axial	2.861	5.225	2.838	5.182	2.135	3.898	4.519	8.253	4.694	8.572

Figure 2. Radial, tangential & axial spatial resolution, in FWHM and FWTM mm, averaged between 2 axial slices at different radial distances from the center of transaxial FOV

Image Quality (uniform hot and cold cylinder compartment)

- Non-uniformity: 18%
- Spill-over ratio: 0.11 for the cold water and 0.07 for air regions

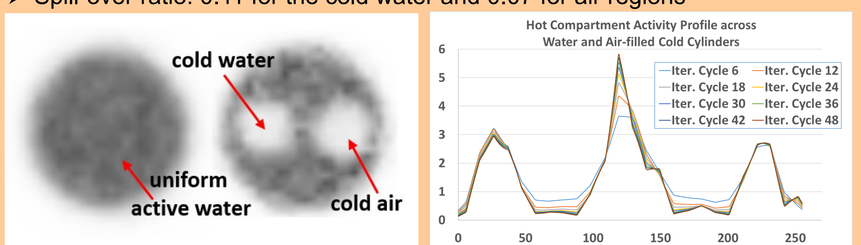


Figure 3: OSEM reconstruction of mouse IQ phantom at the uniform hot (left) and cold cylinder (center) compartments. Line profile across the cold cylinders vs. OS-EM iterations (right)

Uniform hot activity distribution

Mean	Max	Min	%STD
4.862	8.604	2.234	17.975

Cold cylinder spill-over ratio

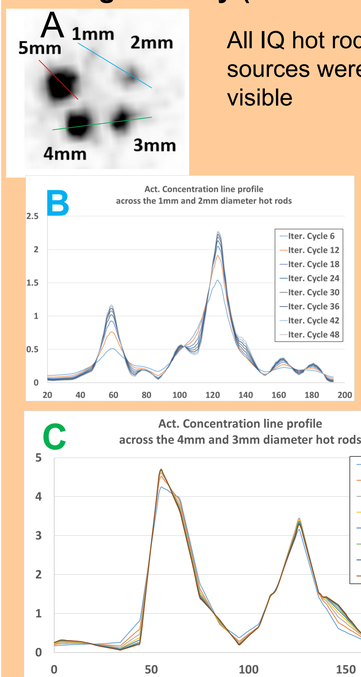
Cold Region	Spill-over Ratio (SOR)	%STD of SOR
Water-filled cylinder	0.110	21.072
Air-filled cold cylinder	0.070	19.293

REFERENCES

[1] H. Zaidi and N. Karakatsanis, Br J Radiol, 91(1081), 2018.
[2] M. Bentourkia and H. Zaidi, PET Clin, 2(2), 2007.
[3] P. Zanotti-Fregonara, *et al, J Cereb Blood Flow Metab,* 31(10) 2011.
[4] K. Thielemans et al., Phys Med Biol, 57(4) 2012

RESULTS *(… continued)*

Image Quality (Hot Rods)



All IQ hot rod sources were visible

Figure 4:.(A) Reconstructed image of the mouse IQ phantom at the hot rod compartment. Colored line profiles across the center of the (B) 1mm and 2mm, (C) 3mm and 4mm, and (D) 5mm hot rods show enhanced peak-to-valley ratio with increasing OS-EM iterations (4 subsets)

Rod Diameter	1mm	2mm	3mm	4mm	5mm
%Recovery Coeff. (RC)	21.777	40.616	58.350	86.352	96.211
%Std.Dev. (STD) of RC	28.121	26.720	21.071	20.220	19.521

Sensitivity

- System sensitivity: 3.54kcps/MBq
- Max. volume sensitivity @ center of axial FOV: 5.6kcps/MBq/slice

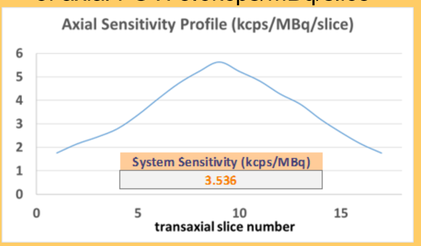


Figure 5. Axial sensitivity profile and the system sensitivity (AUC).

CONCLUSIONS

- The NEMA NU4-2008 spatial resolution, image quality and sensitivity performance of the SynchroPET ArterialPET^{TM} prototype was evaluated.
- ArterialPET can be employed to detect and quantify non-invasively radioactivity from human blood vessels in the wrist
  - estimated vessel diameter in the order of 2-5 mm.